Dipole Survey and Alignment of NSLS-II

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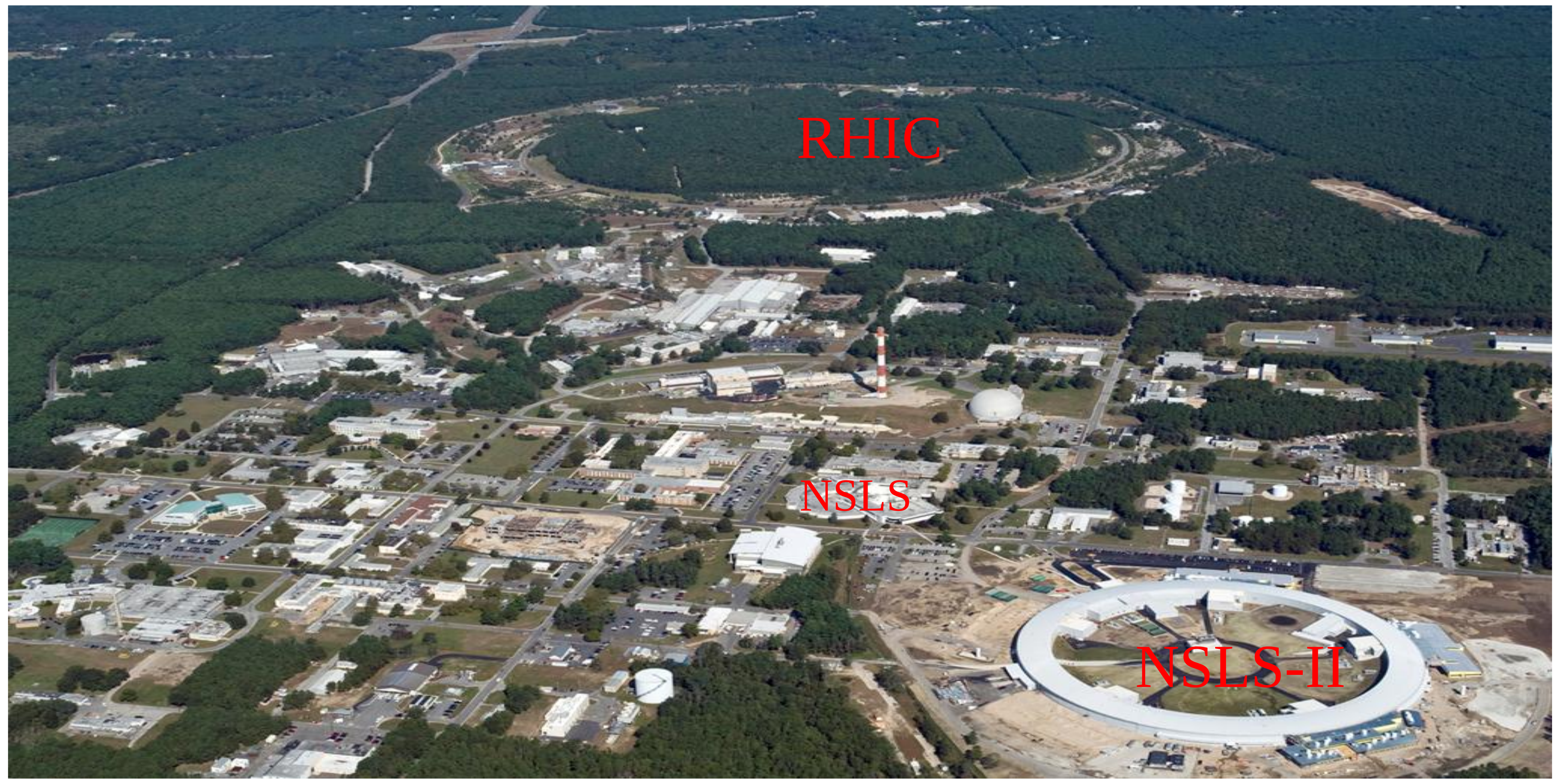
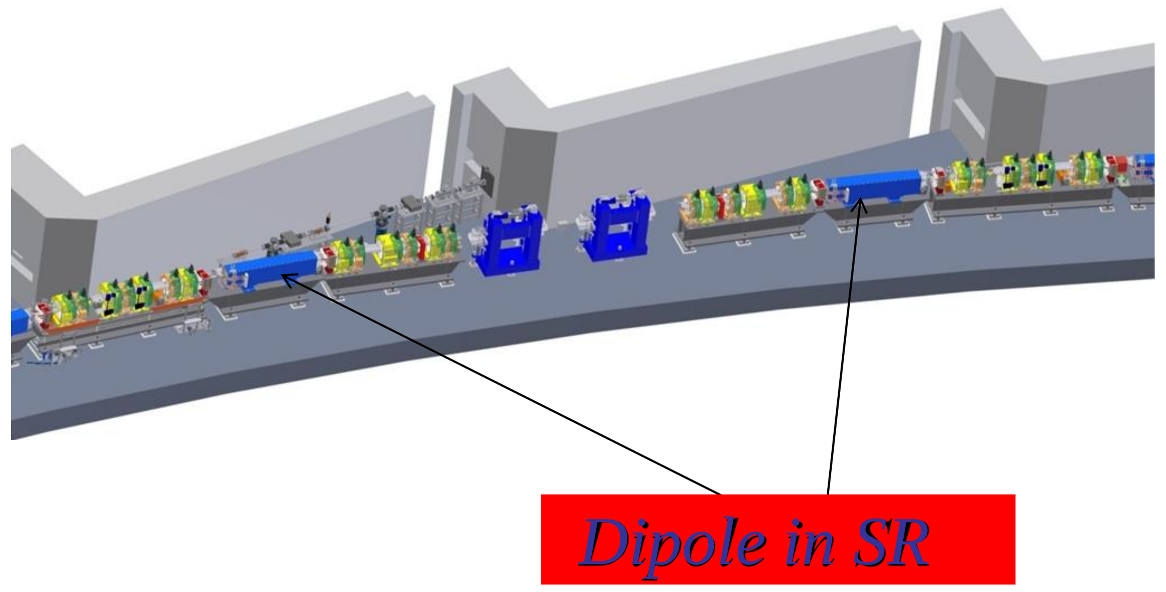
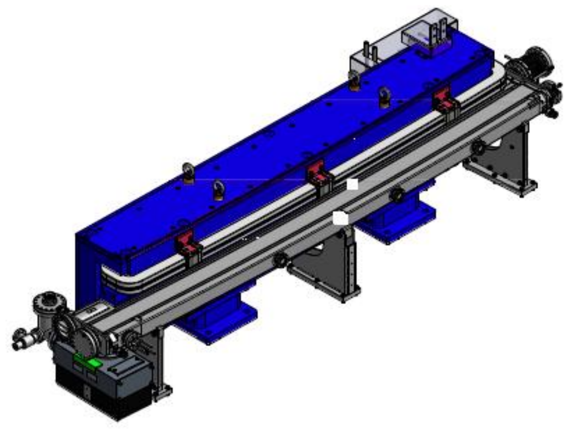
Introduction

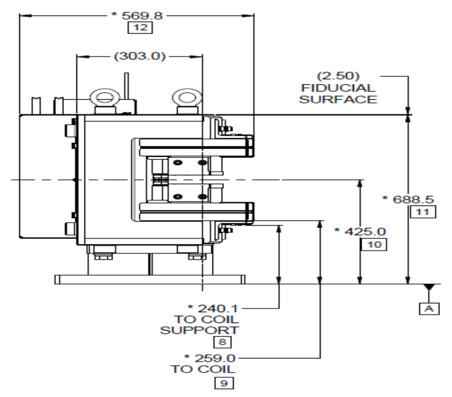
The survey group of Brookhaven National Laboratory (BNL) undertakes the entire alignment task across the lab which includes NSLS, NSLS-II, AGS, RHIC and etc. NSLS-II is an on-going project which will be a new state-of-the-art, medium-energy electron storage ring (3 GeV, 30 DBA) designed to deliver world-leading intensity and brightness with a 0.6 nmrad minimum horizontal emittance when it's fully built out. It will provide 1 nm spatial resolution and 0.1 MeV energy resolution to facilitate the study of nanostructures. Its circumference is 792 meter with the potential of at least 58 beamlines. The construction of the NSLS-II's ring building began in March 2009 and it's scheduled to be in full operation in June 2015.

There are 60 dipole girders and 90 multipole girders totally. NSLS-II project requires ±100 micron alignment accuracy between girders. The work associated with dipoles can be categorized as pre-survey portion and alignment portion. The pre-survey of dipoles includes mechanical frame establishment, manufacturing dimension and vacuum clearance verification. The alignment portion includes the positioning of dipole relative to magnetic measurement system and tunnel positioning relative to control network.









Dipole Parameters			
Dipole Type	Type	A	B
Aperture, minimum	mm	35	90
Operating DC Field	T	0.4	0.4
Magnetic Length	mm	2620	2620
Radius of beam axis	m	25.02	25.02
Tolerance on yoke radius (±)	mm	50	50
Yoke Length, nominal	mm	2584	2528
Lamination Thickness, nominal	mm	1	1

The Characteristic of Dipole

Dipole are laminated but have machined pole surface which means the pole surface can represent the geometry information and be used as survey reference.

Compared with multipoles, the magnet dimension is bigger. Laser tracker, not articulated arm, with scanning capability is used to perform the survey.

Dipole Pre-survey

When a dipole is ready to be inspected, there are 3~4 laser tracker setups in order to capture all the information needed. The measurement elements include:

☞Common targets are measured during each setup to orient instruments. Unified Spatial Metrology Network (USMN) of Spatial Analyzer (SA) is used to get the optimal coordinates.

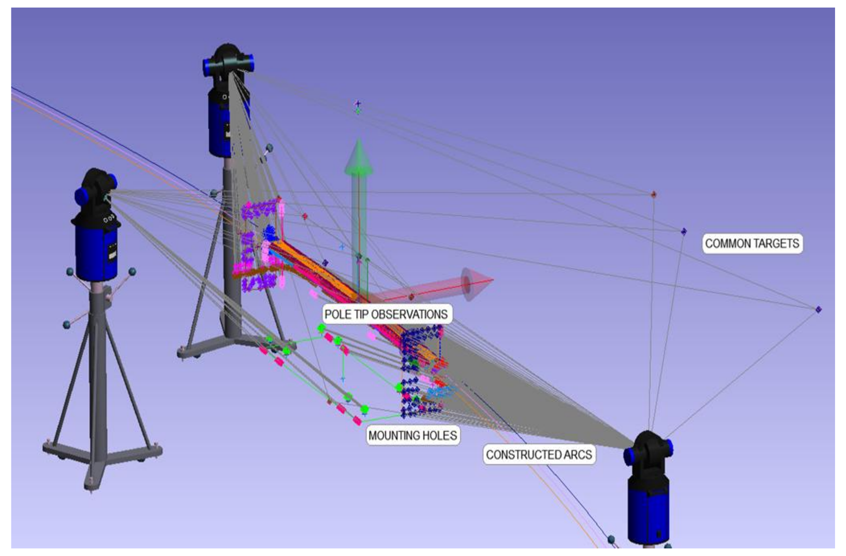
☞Pole surfaces points are measured to define the horizontal plane and can be used to compute the aperture of the dipole.

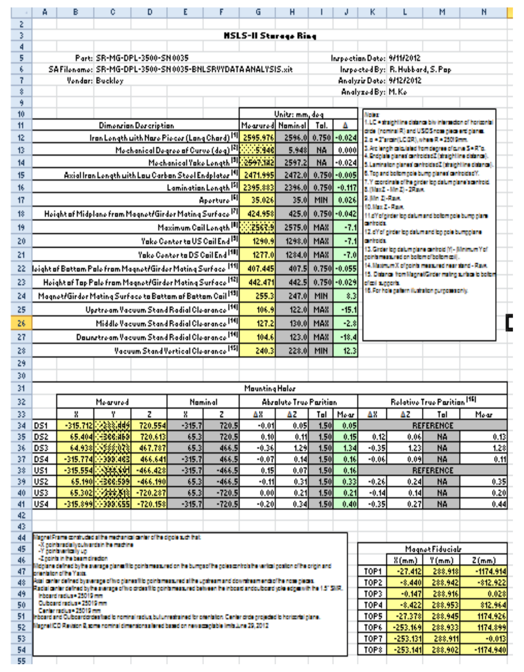
☞Points are measured on the upstream and downstream end of the top and bottom poles to control the beam longitudinal position.

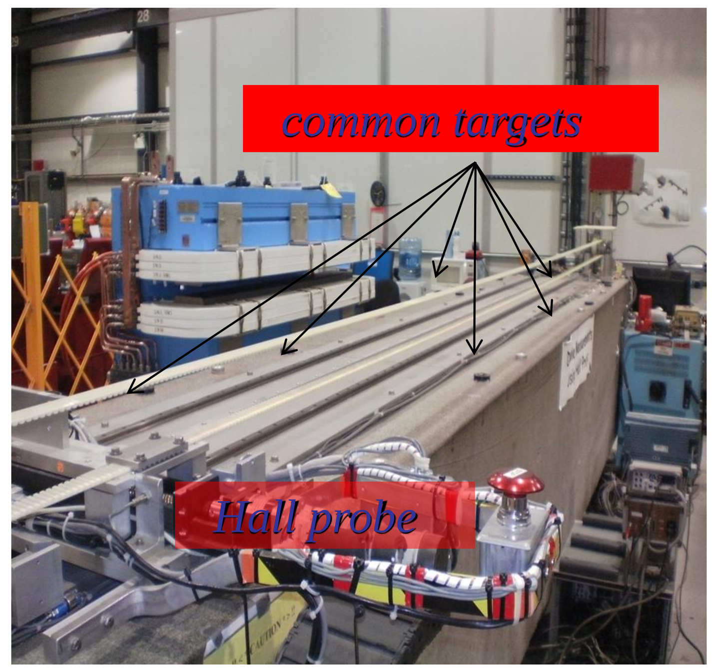
☞Inboard and outboard circle points can determine the bending radius. The bisected circle defines the beam orbit.

☞The magnet frame can be established and the information is ready for further alignment.

☞Some measurements are dedicated for Interface Control Drawing (ICD) check purpose, such as the end and bottom of coil position, mounting holes in the base etc. Inspection report will be generated for each dipole. Discrepancy report will be submitted if the dimension is out of tolerance.





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// SpatialAnalyzer SA 2012.07.09
// Points Relative to Coordinate Frame 'A::MIDDLE OF PROBES AT
HOME-6-10-11'
// AXES = CARTESIAN: X,  Y,  Z [Millimeters]
US MEAS,  200.632991,  0.001402,  3606.423923
C MEAS,  166.964773,  0.001429,  2308.331910
DS MEAS,  200.692471,  -0.005951,  1010.239900
US RNOM,  200.633003,  0.044741,  3606.424098
ORIGIN RNOM,  166.964775,  0.035352,  2308.332028
DS RNOM,  200.692469,  0.021688,  1010.239980
RADIUS POINT,  25185.964718,  -1.551501,  2308.904342
DPL-3500-SN 0024 ORIGIN,  166.964775,  0.035352,  2308.332028
DPL-3500-SN 0024 X AXIS,  -833.035222,  0.098778,  2308.309152
DPL-3500-SN 0024 Y AXIS,  167.028201,  1000.035350,  2308.323150
DPL-3500-SN 0024 Z AXIS,  166.987650,  0.026473,  1308.332028
HOME ORIGIN,  0.000000,  0.000000,  0.000000
HOME X AXIS,  1000.000000,  0.000000,  -0.000000
HOME Y AXIS,  0.000000,  1000.000000,  0.000000
HOME Z AXIS,  0.000000,  0.000000,  1000.000000

Notes:
A "BEAMLINE" circle is built so that it is at the mechanical
center of the magnet with the nominal radius (25019 mm).
The US and DS planes are defined by the ends of the noses and
the vertical midplane is the bisection of these.
US RNOM, ORIGIN RNOM, and DS RNOM are points where the
"BEAMLINE" circle passes through these vertical planes.

The new points US MEAS, C MEAS, and DS MEAS are the three points
from which the "BEAMLINE" circle is made.
These have different elevation coordinates (Y) because the
"BEAMLINE" circle is not only made with a fixed radius, but
also is projected to the HORIZONTAL MIDPLANE based on the
measured "bumps" of the poles.

RADIUS POINT is the center of the magnet's "BEAMLINE" circle.
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Dipole Alignment Relative to Hall Probe

Dipole needs to be aligned to the Hall probe (HP) bench for magnetic measurements. In order to enhance magnetic measurement precision, the alignment goal of dipole relative to trajectory of HP is better than ±100 micron and the residuals of roll, pitch and yaw should be minimized.

The main steps are listed in the following:

☞HP frame was built at the beginning according to the movement of the probe and the supporting granite. The coordinates system (CS) can be represented by the monuments glued on the granite surface.

☞Laser tracker will be used to measure the monuments to retrieve the HP frame and direct the adjustment of dipole.

☞Use the watch window to get all the top fiducials zeroed in elevation direction. The small yaw residual is achieved by keeping the X reading of upstream and downstream fiducials almost the same.

☞The alignment residuals will be reported to magnet group for further analysis.

Instrument and Software

The major instruments used in NSLS-II project are laser trackers, articulated arms and total stations. In the early stage, mekometer and digital level were used to establish the primary and elevation control network, but they were phased out.

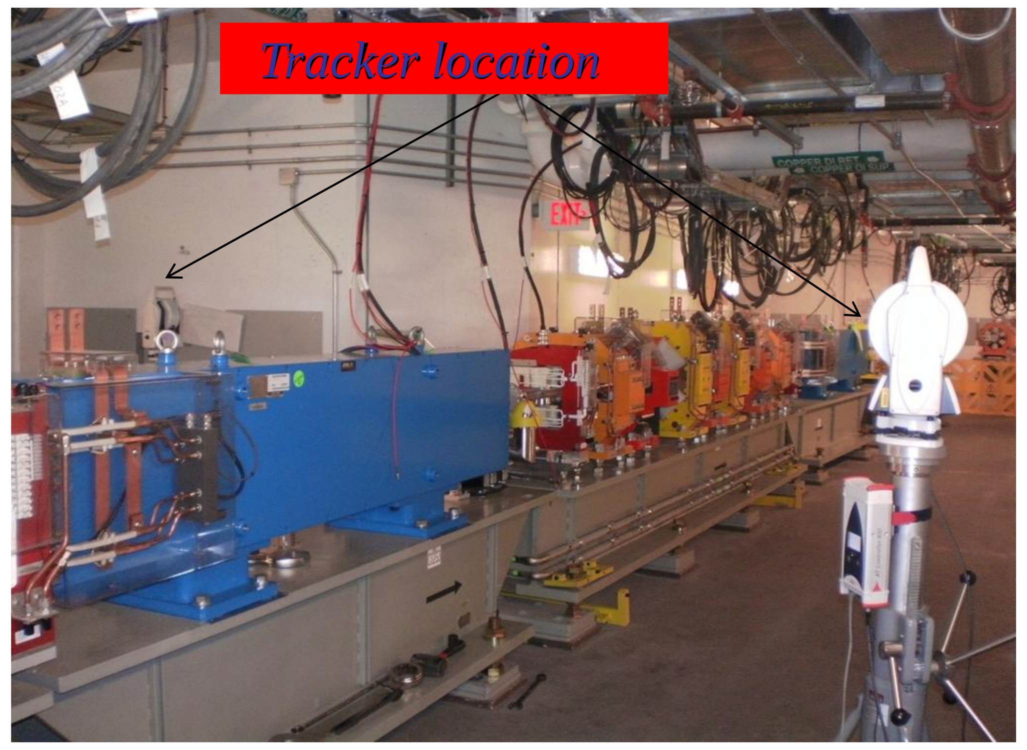
Star*net is used to analyze the control network data initially and double check the data obtained from SA occasionally. The major software in use is SA. We have 12 SA keys to ensure the seamless transfer of data among the group members. The uniform interface and versatile functionality of the software is very helpful to the project. Especially, the data analysis for dipole pre-survey can be automated with the help of the Measurement Plan (MP). It has been proven to be very effective. Although the writing and debugging MP need some time, the result can be provided in a timely manner after the raw data is obtained.

Dipole Installation in Storage Ring

Dipole girder installation in storage ring (SR) will be a 2-step process.

☞Dipole girder will be aligned relative to control network with about ±200 micron precision. Similar with the alignment of multipole girders, two trackers will be employed at the same time to streamline the adjustment process. There has been about 1/5 of the dipole girders have been aligned this way by the end of August, 2012.

☞Next year, when the settlement of tunnel stabilizes and the environmental control are fully in action, multipole girders will be gone through a very precise girder profile reproduction process as reported in this workshop. Along with that kind of activity, dipole girder will be re-aligned relative to the adjacent multipole girders and the girder alignment specification will be pursued and achieved.



Alignment Error Estimate

Dipole girder alignment error can be estimated based on the following error source:

☞Pre-survey precision: ~± 50 micron.

☞Tunnel control network: ~± 70 micron.

☞Alignment residual: ~± 50 micron.

The final alignment precision is about ± 100 micron.

Acknowledgment

The authors would like to thank all the staff who got the work done.

Questions? Ask me ...

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U.S. DEPARTMENT OF ENERGY

12th International Workshop on Accelerator Alignment (IWAA 2012)

September 10-14, 2012 Fermilab, Batavia, Illinois, US

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